

## Chapter 2

# Estimate of PRNU Noise Based on Different Noise Models for Source Camera Identification

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### ABSTRACT

*Identification of the source that has generated a digital content is considered one of the main open issues in multimedia forensics community. The extraction of photo-response non-uniformity (PRNU) noise has been so far indicated as a mean to identify sensor fingerprint. Such a fingerprint can be estimated from multiple images taken by the same camera by means of a de-noising filtering operation. In this paper, the authors propose a novel method for estimating the PRNU noise in source camera identification. In particular, a MMSE digital filter in the un-decimated wavelet domain, based on a signal-dependent noise model, is introduced and compared with others commonly adopted for this purpose. A theoretical framework and experimental results are provided and discussed.*

### INTRODUCTION

Digital forensics science emerged in the last decade in response to the escalation of crimes committed by the use of electronic devices as an instrument used to commit a crime or as a repository of evidences related to a crime (e.g., piracy and

child-pornography). For instance a digital camera could be the instrument used to commit a crime and/or a digital photograph, being the evidence related to an illegal action, might have been altered to mislead the judgment. One important element of digital forensics is the credibility of the digital evidence in order to assess digital data origin and authenticity. In this paper digital images are taken in account focusing on evaluating image origin

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determining the specific digital camera which has acquired that content. It is possible to split the source identification problem in two fields (Lanh, 2007): the first is devoted to determine the specific digital camera or scanner and also identify the model and brand that acquired an image (Bayram, 2005; Chen, 2008; Lukas, 2006; Swaminathan, 2008; Sorell, 2009), the second one is dedicated to investigate the kind of device (Caldelli, 2009a; Caldelli, 2009b; Khanna, 2008) that has generated the image under examination (digital camera, scanner, computer graphics images). Various solutions have been proposed in literature to solve the source identification problem analyzing the digital device acquisition process in order to find a fingerprint left by the device like the use of Color Filter Array (CFA) characteristics (Swaminathan, 2008; Bayram, 2005) and the Photo Response Non-Uniformity (PRNU) noise (Caldelli, 2009b; Khanna, 2008; Chen, 2008; Lukas, 2006). The PRNU noise is induced by intrinsic in-homogeneities over the silicon wafer and imperfections generated during sensor manufacturing process of CCD/CMOSs. The PRNU is used as sensor fingerprint and it is commonly employed to solve the problem of digital camera sensor identification. Such a technique is investigated in this paper. The extraction of PRNU noise happens through a digital filtering operation from a set of digital images taken by a camera. After that, the PRNU noise of the to-be-checked image is extracted and compared with the available fingerprints and then the image is classified as taken (or not) by a certain camera. It is important to point out, for the further discussion, that the PRNU noise is deterministically embedded in each image the sensor acquired.

In this paper we propose a method for estimating the PRNU noise introducing a MMSE filter in the un-decimated wavelet domain described in (Alparone, 2006). The application of this filter in forensic domain is novel, generally it is adopted for speckle and film-grain noise removal in coherent radiation imaging systems including ultrasound,

infrared and laser imaging and synthetic aperture radar (SAR).

So we present a theoretical and experimental comparative analysis of different wavelet denoising filters to estimate the PRNU in order to solve the digital camera identification problem. We used the filter described before and the filter proposed in (Mihcak, 1999) and then used in (Chen, 2008).

Introducing the filter in (Alparone, 2006) we make an assumption that the digital camera noise is considered as dependent on the sensed signal, while using the already known filter described in (Mihcak, 1999) a signal-independent noise model is supposed. Furthermore, the two filters are based on different noise models and in particular the novel filter noise model (Alparone, 2006) more accurately captures the image generation model of a digital camera.

The paper layout is the following: the two denoising filters are introduced, in we then describe the digital camera sensor output model that will be used to derive the estimation of PRNU and the noise models for the two filters will be discussed. Some experimental results are the presented to evaluate the de-noising filters performances.

## **DE-NOISING FILTERS**

According to PRNU methodology, it is crucial to analyze the type of de-noising filter to be used for the extraction of such a noise. In this work we have decided to compare the MMSE filter operating in the un-decimated wavelet domain (Alparone, 2006), named Argenti's Filter, with a spatially adaptive statistical modelling of wavelet coefficients filter (Mihcak, 1999), and named Mihcak's Filter. The first one is based on a signal dependent noise model; on the contrary the second one adopts a simple additive noise model. For sake of completeness a simple low-pass filter in the wavelets domain (LP Filter) has been considered too, to provide a performance lower bound

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